TEST OF A 40 H. P. HALLADAY AUTOMOBILE CHASSIS

BY
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A. W. SEMERAK

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Chasis

TEST OF A 40 H. P. HALLADAY CHASSIS

A THESIS

PRESENTED BY

A. F. FORS
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A. W. SEMERAK

TO THE

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HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

MECHANICAL ENGINEERING

MAY 29, 1913

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PREFACE

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PART I

STUDY AND CALIBRATION

OF KENERSON DYNAMOMETER

PART II

TEST OF THE CHASSIS

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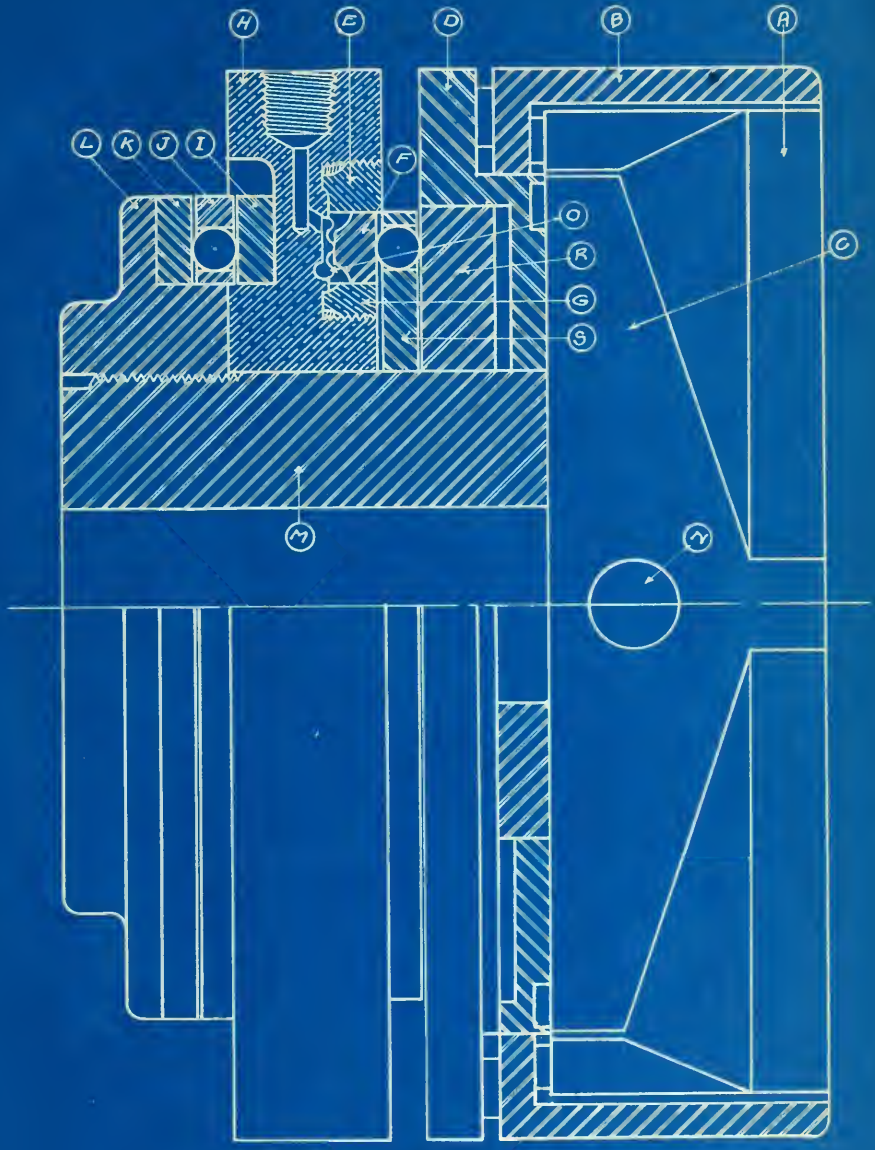
PLATE 1



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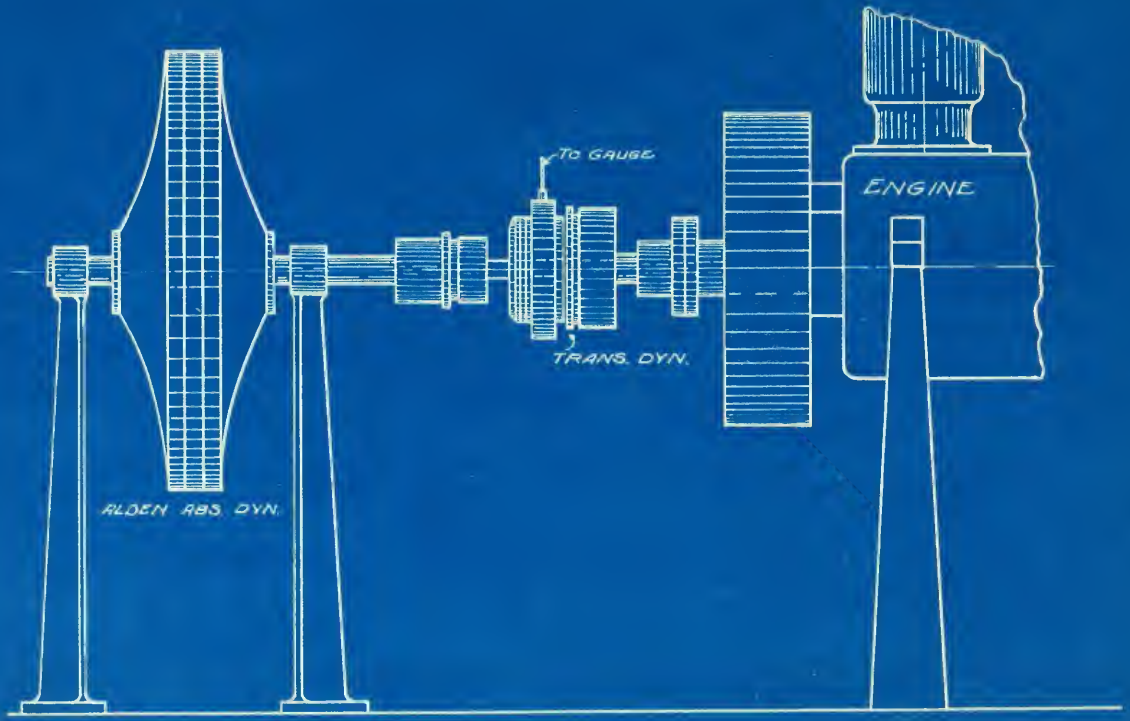

PLATE II

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PLATE III

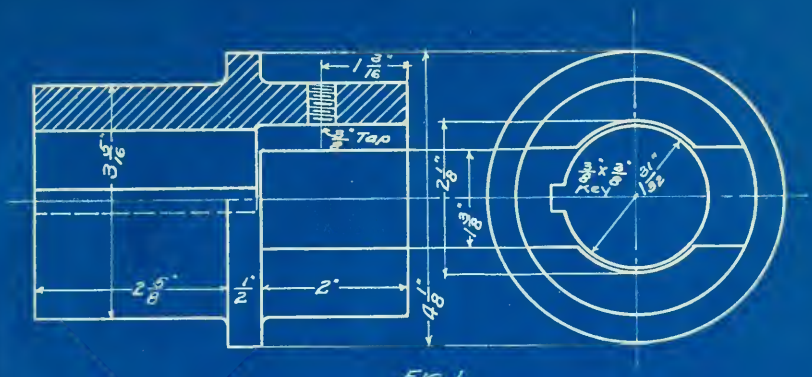

FIG. 1

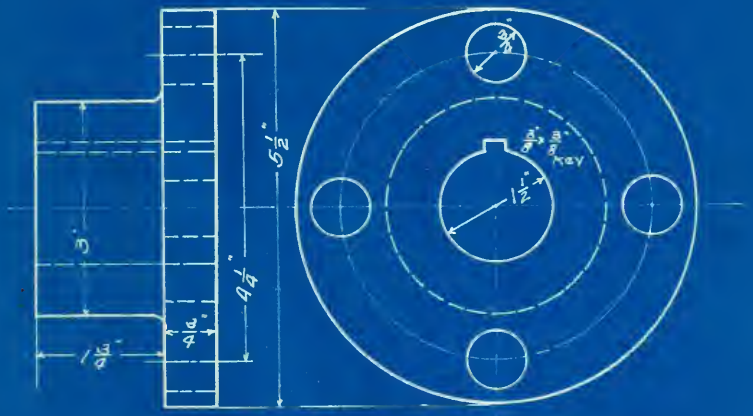

FIG. 2.

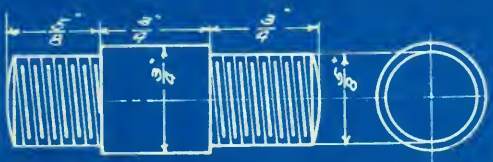

FIG. 3.

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PLATE IV

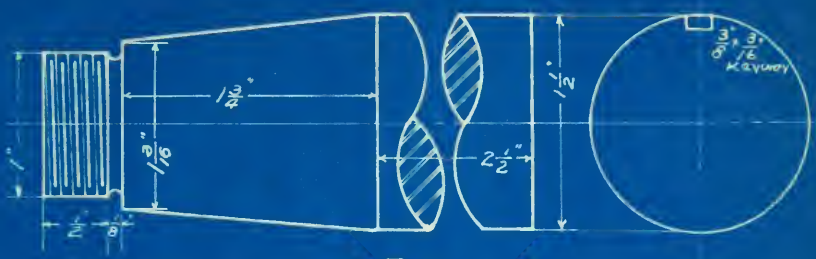

FIG. 1

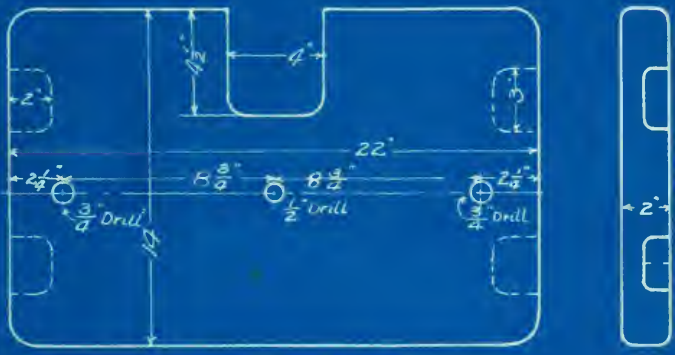

FIG. 2

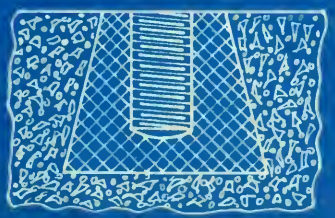

FIG 3

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PLATE V

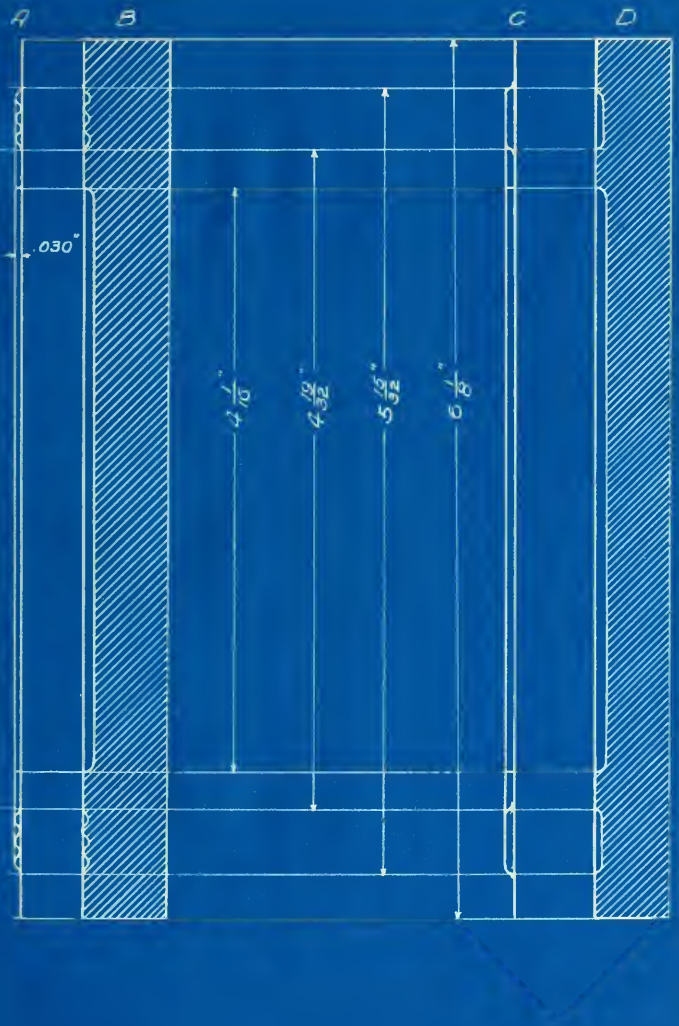

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Plate III- Details of Calibrating Apparatus

Plate IV - Details of Calibrating Apparatus

Plate V - Details of Diaphragm

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The automobile to-day is recognized as an important factor entering into the transportation problems. Up to a few years ago, it was classed as a purely pleasure vehicle but at the present time the auto truck has replaced the horse in many instances. Although this discussion pertains to the pleasure car only it can be applied equally well to the commercial car. The average purchaser of the pleasure car is interested primarily in the external characteristics of the machine, but ultimately the fuel bill is of importance to him.

Economic operation signifies relatively low operating expense. The car with the highest over all efficiency is of course the one which should be sought. The maximum efficiency can only be obtained when the relation between the horse power developed by the engine and that realized in actual propulsion is of a maximum value. It is therefore the object of this thesis to ascertain this relation in the apparatus at hand.

The gasoline engine of today has reached a high degree of perfection and consequently its

efficiency and economy of operation are satisfactory. However, before its power in the automobile finds its way to the rear wheels it must be transmitted through various parts. First, we have the clutch. This of course is used for disengaging the engine from the load and is of two types, namely, cone and multiple disk. Next is the transmission gearing for the purpose of varying the ratio of the engine speed to that of the rear wheels. This is also of two distinct types, namely, selective and progressive. Then there are one or more universal joints between the transmission and the differential gearing, the latter serving as a medium to permit the rear wheels to run at different speeds when necessary. Finally we have the actual motive apparatus, the rear wheels. These parts, together with the front wheels, steering column and frame are assembled into a unit, the chassis.

To determine the loss of power in these several parts the power delivered by the engine must be measured. This is done by the use of the Kenerson transmission dynamometer. Again the power

delivered by the rear wheels must be absorbed and this is done by means of an Alden absorption dynamometer which is a water brake. The difference between the transmitted power and the absorbed power, is, of course, the loss due to the transmitting mechanism. The ideal position of the transmission dynamometer is immediately behind the engine, but since this was impossible on the apparatus tested it was placed between the clutch and the transmission.

Since the determination of the power output of the engine is one of the most important factors entering into the efficiency, a thorough study was made of the Kenerson dynamometer. A considerable amount of time was spent on it and the calibration of this instrument is considered separately under part I.

The actual test of the chassis constitutes part II.

Part I.

Study and Calibration of the Kenerson Transmission Dynamometer.

Although this part of the apparatus failed during the test, the preliminary work done in this connection is of value both for the training received and the facts noted.

The Kenerson dynamometer which utilizes the turning effort or torque of the revolving part is shown in partial section in plate I. It consists essentially of two half coupling A and M_1, A being connected to the source of power, which are bolted together and yet have motion with respect to each other about their common axis. This motion is obtained by enlarging the holes in one of the couplings. Thus no power could be transmitted unless the bolts had a bearing in the hole, or unless the concentric motion were retarded which is what actually takes place.

When power is applied, A, having a tendency to rotate with respect to M, acts on C which in

effect is a double bell crank pivoted at N. There are four of these bell cranks having bearing points at their extremities. Rotation in either direction can be transmitted by the double crank. Motion of C will cause the other parts to have a tendency to move away along the axis. This movement is arrested by the lock nut L. Between L and B, and consequently C, is located H, which contains the power measuring device, O. This is a phosphor bronze diaphragm, corrugated to give elasticity, whose motion is resisted by a body of oil.

Now when A moves C, the ring F is forced against O and since the movement is confined between C and L, a pressure is exerted on the oil and this pressure is measured by an ordinary pressure gauge, H being held stationary. E and G are brass nuts for clamping the diaphragm to H. Thrust bearings are formed by F,R,S and K,J,I, respectively, K,I,R, and F being hardened steel races while J and S are the ball retainers. B and D each contain two

knife edges whereby friction is reduced to a minimum. Since the axial motion is caused by the turning effort, it follows that the pressure on the oil is proportional to the torque exerted.

In as much as the calibration in the torsion machine was not considered as representing actual operating conditions, other means of calibration were resorted to. The apparatus available consisted of a four cylinder Reutenber motor identical with the one in the chassis, connected to an Alden Absorption dynamometer by means of a flexible coupling. However, before this could be used, several parts had to be made. Fig. 1, plate III, shows a coupling, one end of which is fitted to the brake shaft, while the other holds one end of the universal joint attached to the transmission dynamometer. In fig. 2 is shown a half coupling which is fastened to that on the engine shaft by four studs similar to the one shown in fig. 3. Fig. 1, plate IV shows a taper shaft fitted to the dynamometer and to the coupling half and by means of which

the dynamometer is secured to the engine.

It was found that the Alden dynamometer had to be moved away from the engine about eleven inches. Since it rested in its original position on two cast iron plates set into the concrete floor about one quarter inch below the surface, a new bearing had to be provided for the outer support. This necessitated cutting a recess and providing some means of bolting down. Beneath each hole in the support, a square taper hole was cut into the floor with the larger end down. With all parts cap screws coated with white lead to prevent sticking, were put in the holes in the support and molten zinc was poured around them, filling the square hole.

In this a thread was cast which saved the operations of drilling and tapping, had the hole been filled. Details of this part of the floor are shown in Fig. 3, plate IV. This method of anchoring proved entirely satisfactory.

Plate II shows the dynamometer in series with the engine and brake ready for calibration.

The gauge was rigidly attached to the dynamometer at the taper hole in H, plate I. At the lower speeds the gauge gave fair indications, while at higher speeds it was impossible to make an accurate reading for the vibration due to slight eccentricity and to the non rigid support of the universal joint, caused the needle to fluctuate wildly. In addition to this the gauge itself shook so that the divisions on the dial were rendered indistinct.

It was then decided to move the gauge from the dynamometer and mount it on some fixed support connections to be made by means of copper tubing. The small platform, carrying the gasoline tank, suspended from the ceiling of the engine room was found to be convenient for attaching the gauge and the tubing was bent accordingly. Spring action was provided for by forming two spirals on loops.

The tubing used was of one quarter inch outside diameter annealed copper such as is used for gasoline supply pipes on automobiles. The

ordinary connections were at first used but these were found unreliable and regular pipe fittings were substituted, the tubing being soldered in. The gauge during calibration was provided with a temporary wooden support.

Before making the connections the diaphragm and tubing were filled with gas engine oil, care being taken to remove all air possible. The gauge was then connected and placed on the floor bringing the filling hole in H, plate I, into a vertical position. A piece of one quarter inch pipe, about 6 feet long, was inserted, filled with oil, and the whole apparatus allowed to stand over night.

The idea was to force the oil into all portions of the circuit by means of the head of oil in the pipe. The next morning the filling hole was stopped off by means of the plug provided and the gauge and tubing placed in proper position.

Another attempt was now made to calibrate the instrument. Considerable data had been collected when it was discovered that above a

certain load on the engine the gauge indications did not increase with proper regularity. This led to the conclusion tthat a more sensitive gauge might give better results. The original gauge tested out to have a capacity of approximately 60 pounds to the square inch; consequently a thirty pound gauge was substituted.

However no better results were obtained and the dynamometer was subsequently dismantled. This disclosed the fact that the diaphragm had been punctured and hence was valueless. A new one was ordered from the makers and after about eight days one was received, but incomplete, lacking the corrugations. A die similar to B, plate V, was then constructed and a diaphragm of copper, shown at A, approximately six thousandths of an inch thick, formed in the compression machine by using an oiled rubber padding on the copper.

This was inserted and for a few readings showed good results. A sudden load was accidently applied by the siezing of the brake,thus stopping the engine. On resuming the calibration

it was found the readings obtained did not check with the previous ones.

On investigation it was found that the center corrugation had been pressed flat due without doubt to the suddenly applied load. The copper was unable to resist this and received a permanent set. Another material was now considered and phosphorus bronze approximately eight thousandths of an inch thick procured. Another shape was thought to give better service so a die, shown in D, plate V, was made and a diaphragm C formed of the new material.

This was inserted but instead of using gas engine oil, kerosene was substituted to facilitate the removal of the air. The new diaphragm proved to be too stiff, so one was formed from the die B out of the phosphor bronze. Considerable difficulty was experienced in drawing this diaphragm tight but finally leaks were stopped. The new diaphragm showed the thirty pound gauge to be too sensitive so the old gauge was replaced and the instrument calibrated.

The calibration consisted of applying a definite load on the engine as indicated by the scale and as the beam was balanced a reading of the dynamometer gauge taken. The readings were compared by calculating the actual brake horse power as shown by the scale for 100 R.P.M. the total H.P. not being necessary

$$\text{H.P. per 100 R.P.M.} = \frac{2\pi RP100}{33{,}000}$$

$$= \frac{2\pi \times 20 \times 30 \times 100}{12 \times 33{,}000}$$

$$= .95$$

In which

R = length of brake arm

P = net scale reading in pounds

The calibration data is tabulated on an accompanying sheet. A number of runs were made and average readings taken.

Considerable difficulty was experienced with the calibrating apparatus. At times the engine was hard to start and the brake had a tendency to sieze. Due to the heating of the copper plates in the brake it was impossible to ob-

tain figures for lower than thirty pounds on the scale. After the brake had seized it was necessary to cool it for if this was not done the engine could not be turned over for starting. The zero would also frequently change necessitating the resetting of the needle and the thrust collar.

From the difficulties encountered in calibration and from the poor results in the test the authors conclude that this dynamometer is not adapted to this class of work. At low speeds and constant load it may answer, but here it must be firmly supported to prevent vibration.

Part II

Test of the Chassis.

The chassis tested is a 1910 Model Halladay. It is equipped with a four cylinder Rutenber motor, 4 1/2" bore by 5" stroke, multiple disc clutch, and selective type transmission, having three forward speeds and one reverse. The rear axle is of the full floating type. Tires are 36" x 3 1/2" on all wheels mounted on a wheel base of 118 1/2". The rear wheels rest on endless belts running over steel pulleys. On the shaft of one set of these pulleys is located an Alden absorption dynamometer. A more detailed description of this part of the apparatus will be found in the report of Messrs. Bohlander and Kiley of 1912.

Having obtained a calibration of the transmission dynamometer, it was replaced in the chassis and the latter reassembled. Three continuous counters were available, two of them connected to the rear wheels by means of flexible shafting while a third was attachedtto the magneto shaft by supporting it on the frame. At high speed

the vibration of the car shook two of the pointers off of the third counter and it had to be repaired before it was of service. It was then supported independently of the frame and no more difficulty was experienced.

The power transmitted by the wheels to the belts was absorbed by the Alden brake, the horse power being figured as follows:

$$H.P. = \frac{2\,\pi\,RNP}{33{,}000}$$

$$= \frac{2\,\pi \times 18.95 \times 200 \times 220}{12 \times 33{,}000}$$

$$= 13.20$$

where

R = length of brake arm in inches

P = scale reading (net) pounds

N = R.P.M.

In order to obtain a measurement of the tractive effort, it is necessary to resist to a certain extent the tendency of the car to move forward. This is accomplished by suspending a mass of cast iron from the rear of the frame by

means of a flexible steel cable. The weight, made up of six pieces as illustrated in fig. 2, plate IV rests on a platform scale.

To provide a vertical movement of the weights the cable was trained over a pulley supported by two members fastened to the wooden sub-structure. Adjustment in these members was provided but not used. The tractive effort in pounds is the difference between the total weight and that recorded on the scale. The tractive horse power is calculated in the following manner:-

$$\text{Tractive H.P.} = \frac{2\pi RNP}{33{,}000}$$

$$= \frac{2\pi \times 1.5 \times 163.8(767.5-535)}{33{,}000}$$

$$= 10.71$$

where

R = radius of rear wheel

N = R.P.M. of rear wheel

P = tractive weight (total weight scale reading)

In conducting the test one observer was stationed on the driving seat controlling the

spark and throttle. The entire run was made on battery ignition, the magneto having been removed to make room for a new type which did not arrive in time. To start the engine priming had to be resorted to, but often after being primed the engine would start on the spark. With the engine running the clutch was disengaged- high gear thrown in and the car started. High gear or direct drive and full throttle were used throughout the test.

A load applied by means of the absorption dynamometer was of such value as to obtain the maximum pull as shown by the scale, without the engine stalling. When this was obtained it was maintained constant by manipulating the water regulating valves. The spark was set so as to apparently give the best results. The first run was of five minutes duration. The engine speed was then gradually increased by releasing the load and a number of runs made aiming to obtain maximum torque for the given speed. The data collected together with the curves plotted

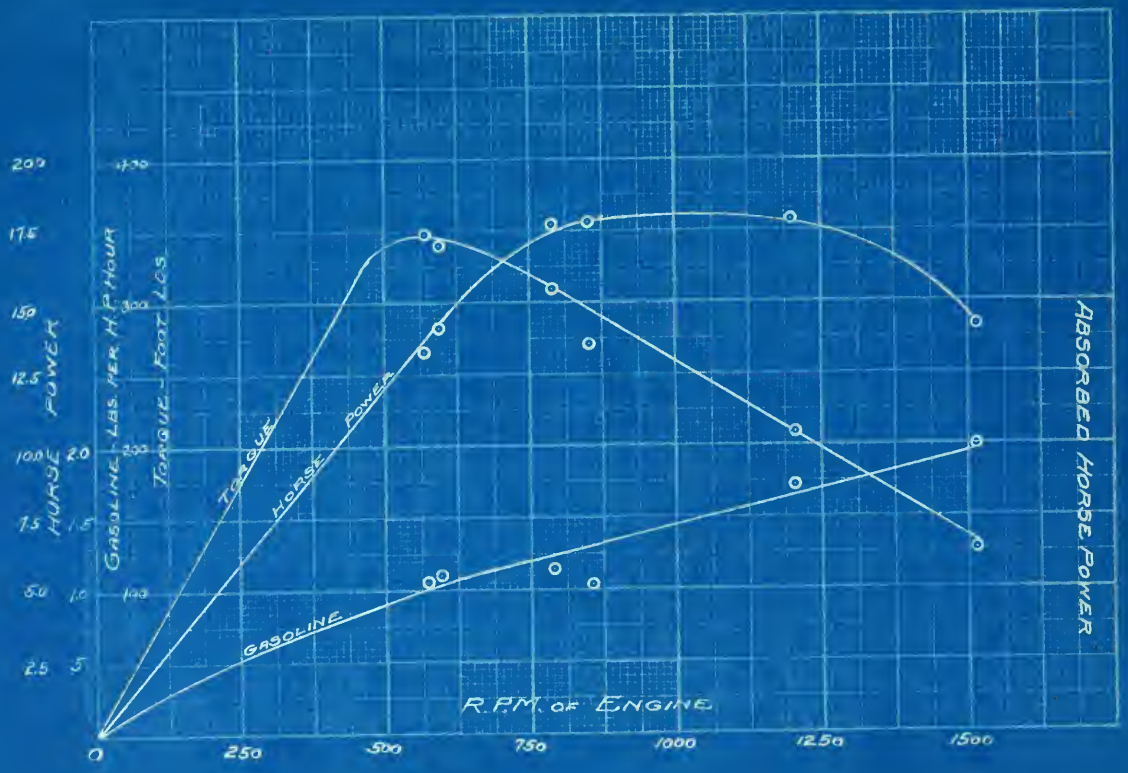
therefrom will be found on accompanying sheets.

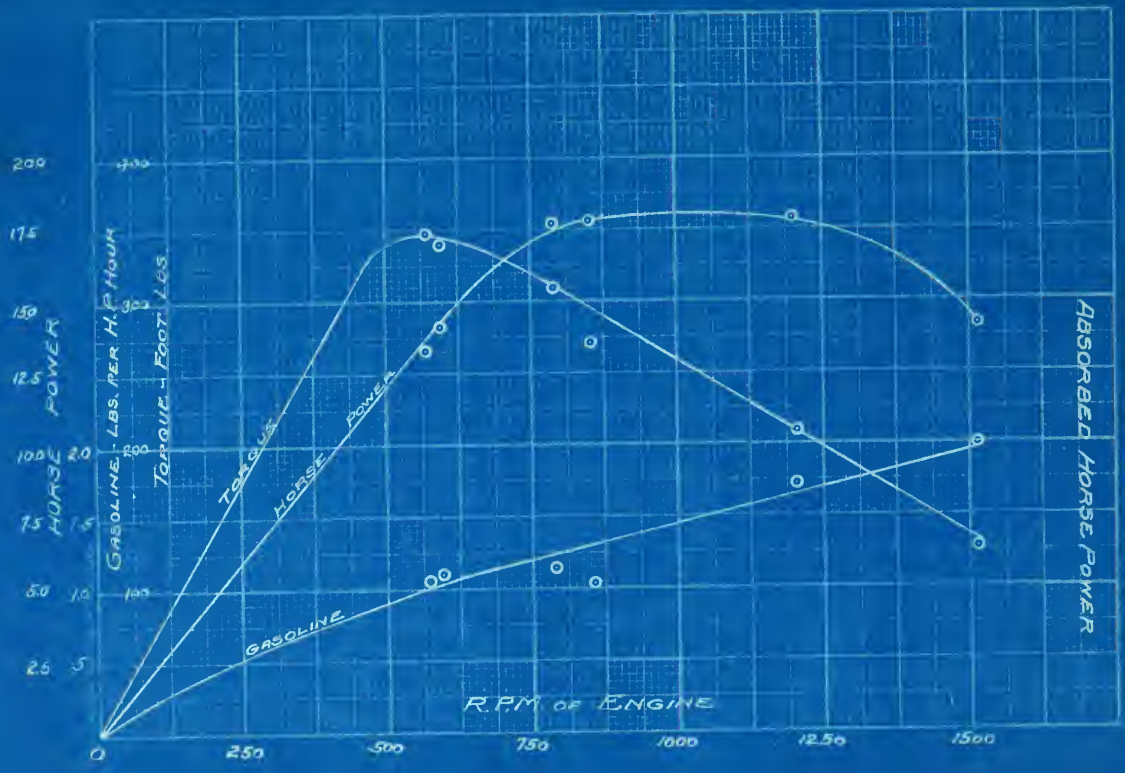
The zero reading on the transmission dynamometer while in use had shifted from its original position and hence a correction was necessary. The traction weight reading for the last run was discarded for having been obtained under difficulties - it gave fictitious results. At the extreme speed the car had a tendency to jump on the belt and thus a true reading of the scale was impossible.

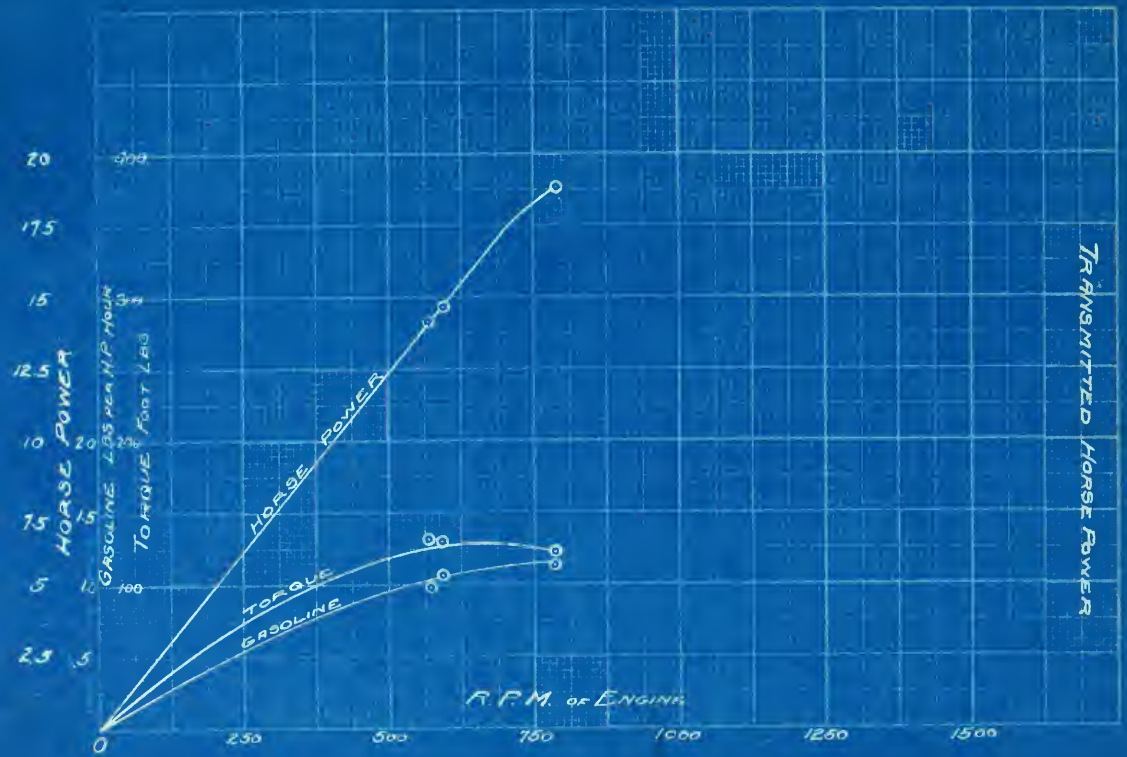
Since the dynamometer failed and the reading obtained being of little value the per cent of the engine power utilized in motive power was not obtained. However, the power transmitted by the rear wheels to the belt, and the tractive effort were obtained, and these together with the gasoline consumption gave a fair estimate of the economy of the apparatus.

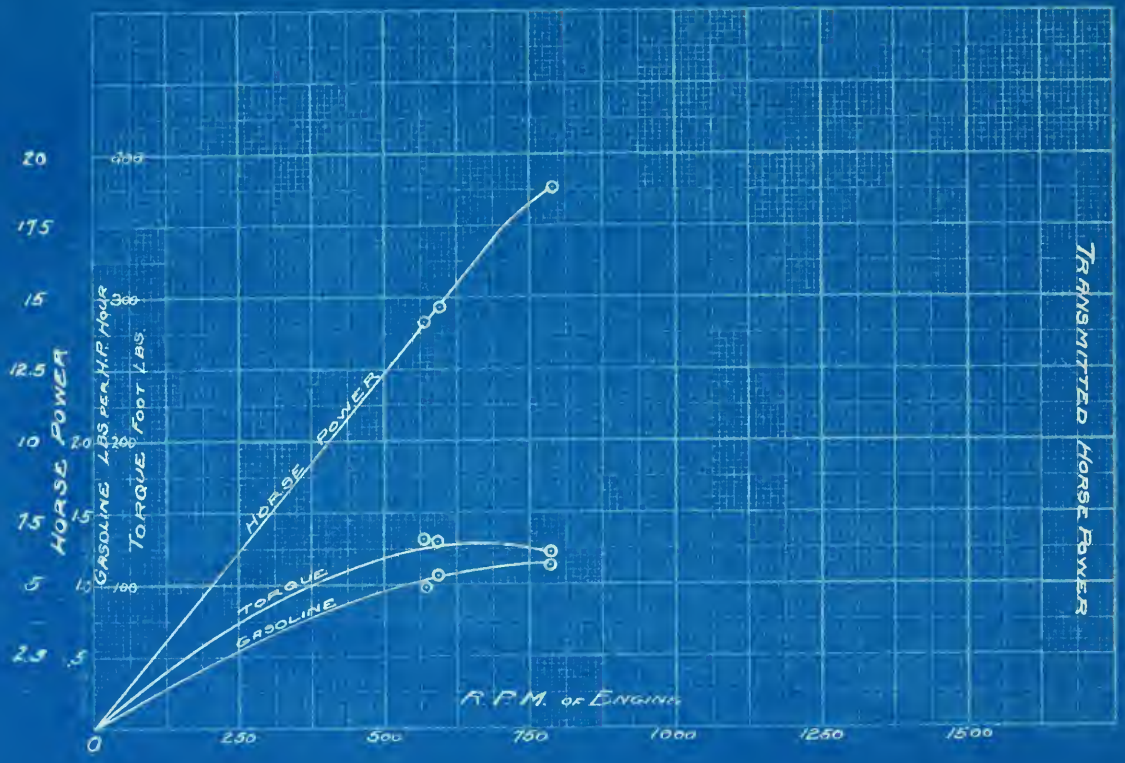
The spark position for the runs is as follows

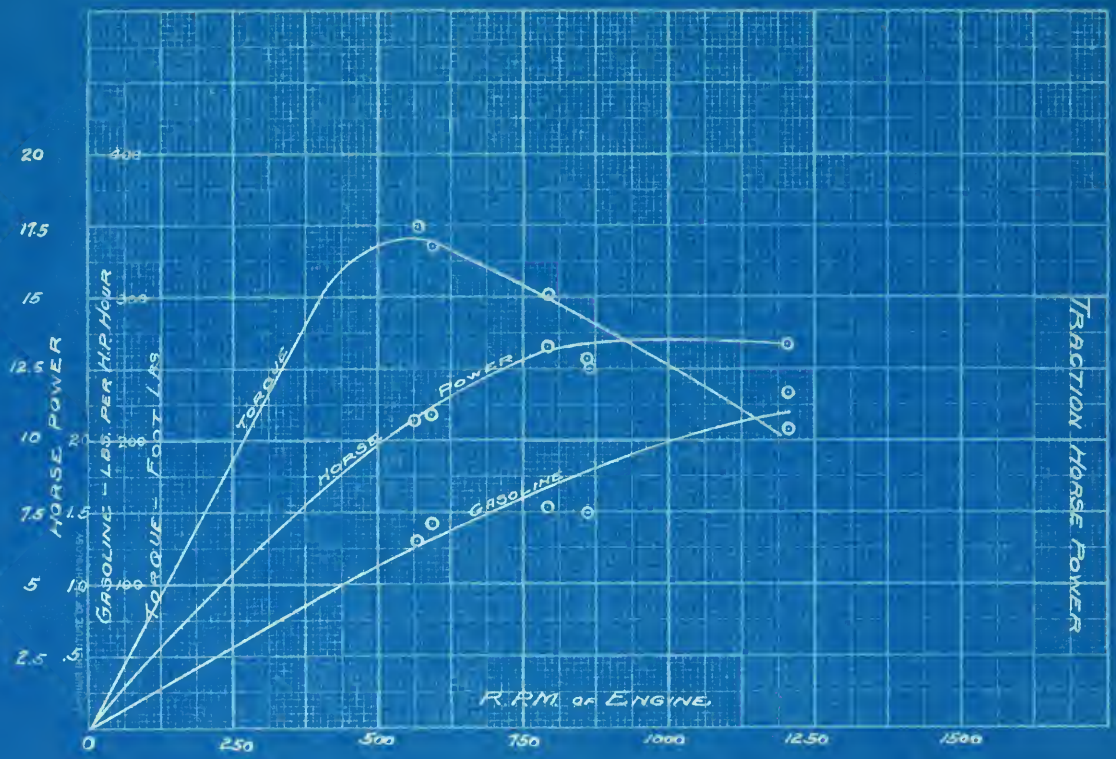
Run #	Spark Position
1	23.6^{0}
2	24.4^{0} "
3	36.8^{0} "
4	57.2^{0} "
5	68.8^{0} "
6	77.4^{0} "


GASOLINE LBS. PER H.P. HOUR
TORQUE. FOOT LBS.
HORSE POWER
ABSORBED HORSE POWER
TORQUE
HORSE POWER
GASOLINE
R.P.M. OF ENGINE
0
250
500
750
1000
1250
1500
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
400
300
200
100
2.0
1.5
1.0
.5


HORSE POWER
200
175
150
12.5
100
7.5
5.0
2.5
GASOLINE - LBS. PER H.P. HOUR
2.0
1.5
1.0
.5
TORQUE - FOOT LBS.
400
300
200
100
TORQUE
HORSE POWER
GASOLINE
R.P.M. OF ENGINE
0
250
500
750
1000
1250
1500
ABSORBED HORSE POWER


HORSE POWER
GASOLINE LBS PER H.P. HOUR
TORQUE FOOT LBS
TRANSMITTED HORSE POWER
HORSE POWER
TORQUE
GASOLINE
R.P.M. OF ENGINE
20
17.5
15
12.5
10
7.5
5
2.5
300
250
200
150
100
.5
1.0
1.5
2.0
2.5
3.0
0
250
500
750
1000
1250
1500


Horse Power
Gasoline Lbs per H.P. Hour
Torque Foot Lbs.
Transmitted Horse Power
R.P.M. of Engine
Horse Power
Torque
Gasoline
20
17.5
15
12.5
10
7.5
5
2.5
400
300
200
100
2.0
1.5
1.0
.5
0
250
500
750
1000
1250
1500


HORSE POWER
GASOLINE – LBS. PER H.P. HOUR
TORQUE – FOOT LBS.
TRACTION HORSE POWER
R.P.M. of ENGINE
TORQUE
HORSE POWER
GASOLINE
20
17.5
15
12.5
10
7.5
5
2.5
300
200
100
1.5
1.0
0
250
500
750
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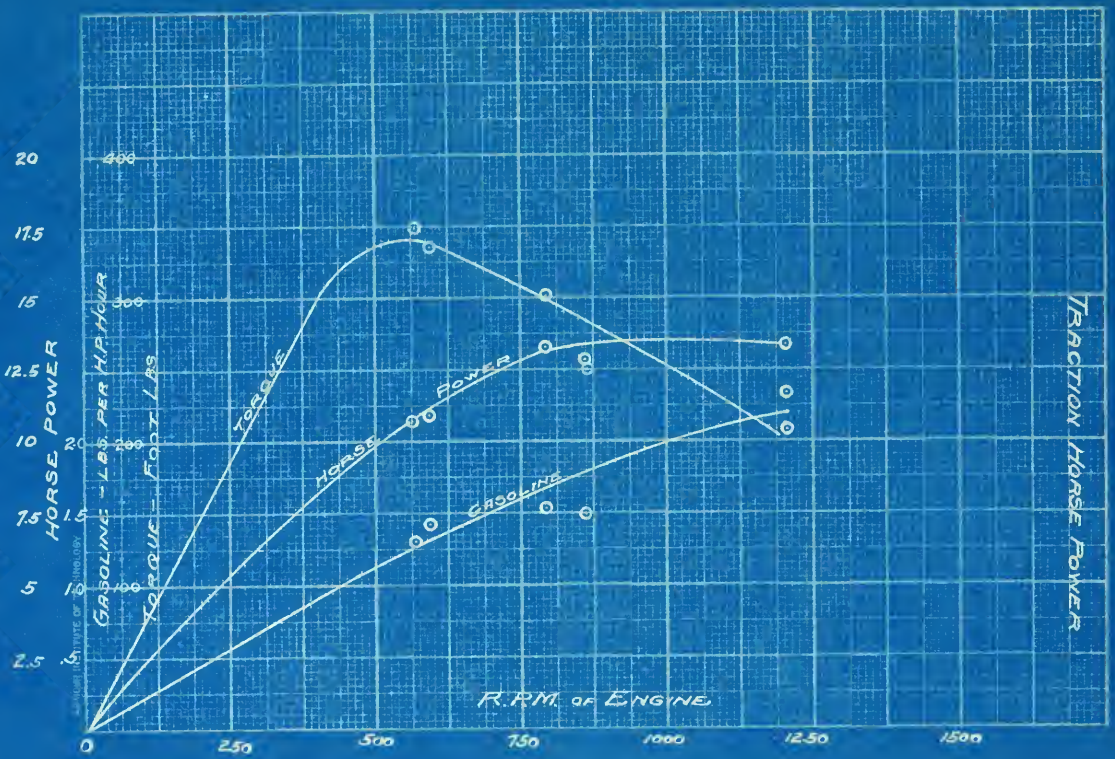
HORSE POWER
GASOLINE - LBS. PER H.P. HOUR
TORQUE - FOOT LBS
TRACTION HORSE POWER
R.P.M. of ENGINE
TORQUE
HORSE POWER
GASOLINE
20
17.5
15
12.5
10
7.5
5
2.5
400
300
200
100
1.5
1
.5
0
250
500
750
1000
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